TITLE OF THE INVENTION

TRACKING GENERATOR WITH INTERNAL VECTOR MODULATION SOURCE

BACKGROUND OF THE INVENTION

The present invention relates to radio frequency (RF) instrumentation, and more particularly to a tracking generator with an internal vector modulation source that is controlled directly by a host RF instrument to perform complex measurements on RF devices.

A tracking generator uses replicas of internal local oscillators of an RF measurement instrument, such as a spectrum analyzer, to create a signal that is at the same frequency that the RF measurement instrument is measuring. The tracking generator is generally provided as an option to the RF measurement instrument. By using the internal local oscillators the tracking generator tunes with a receiver in the RF measurement instrument. In conventional form the tracking generator provides a tuning continuous wave (CW) source that is used to sweep filters, amplifiers and other devices under test (DUTs) as a "poor man's" network analyzer. When used with the tracking generator the RF measurement instrument displays the frequency response of the DUT. Fig. 1 shows how the tracking generator works in conjunction with the receiver and a controller in a representative RF measurement device, where replicas of the internal local oscillators LO1 and LO2 are provided by the receiver to the tracking generator.

Some recent RF measurement instruments have provided an external vector modulation source to generate In-Phase and Quadrature-Phase (I/Q) inputs to the instruments. These allow a user to place an arbitrary modulation

on the CW output of the tracking generator. However when using such an external modulator, the RF measurement instruments require re-calibration whenever the external modulator is exchanged or re-cabled. Also the external modulator is not controllable by the RF measurement instrument. Another disadvantage is that equalization of the tracking generator is not possible.

What is desired is improved measurement accuracy when using I/Q modulation of a CW test signal for measuring RF characteristics of a device under test.

BRIEF SUMMARY OF THE INVENTION

Accordingly the present invention provides a tracking generator with an internal vector modulation source that puts modulation directly under the control of a host RF measurement instrument to allow for accurate measurement of complex parameters such as AM/AM and AM/PM conversion in amplifiers as well as load pull tests. The tracking generator has an internal vector modulation source that digitally modulates complex baseband data from a controller of the host RF measurement instrument to produce a baseband modulation signal. The baseband modulation signal is used to modulate a local oscillator frequency from a receiver of the host RF measurement instrument in an output stage to produce an output or test signal having an output frequency that matches a measurement frequency to which the receiver is tuned. By controlling either the complex baseband data from the controller, an adaptive filter at the output of a DAC that produces an

analog signal from the digitally modulated complex baseband data, an internal independent oscillator for the vector modulator, or a large offset phase-locked loop at the output stage, an offset from the measurement frequency may be generated for the output frequency ranging from small to large (1GHz or greater).

The objects, advantages and other novel features of the present invention are apparent from the following detailed description when read in conjunction with the appended claims and attached drawing.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Fig. 1 is a general block diagram view of an RF measurement instrument with a tracking generator including an internal vector modulator according to the present invention.

Fig. 2 is a representative circuit diagram view of the tracking generator of Fig. 1 according to the present invention.

Fig. 3 is a graphic view of a DAC output spectrum illustrating the use of an adaptive filter to select an offset frequency band according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention integrates an internal vector modulator **12** for the function of generating complex (I/Q) modulation into a tracking generator **20** of a host RF measurement instrument **10**, such as a spectrum analyzer. This puts the modulation directly under the control of a controller **40** in the host RF

measurement instrument **10**. Such control allows for accurate measurement of complex parameters such as AM/AM and AM/PM conversion in amplifiers as well as load pull tests. The tracking generator **20** also may generate two or more tones for inter-modulation tests. Combined with an FFT-based RF measurement instrument **10**, inter-modulation measurements are made without sweeping either local oscillator (LO), allowing for a fixed frequency measurement over a limited bandwidth. The tracking generator **20** also may be combined with an offset capability to place realistic digital modulation in one frequency band of a device under test (DUT) **15** while the receiver **50** in the host RF measurement instrument **10** is tuned to measure another band. When combined with an external channel filter, demanding measurements like adjacent channel leakage ratio (ACLR) may be performed. In such a measurement mode if one LO of the receiver **50** should have to change slightly, the vector modulator **12** compensates in frequency within a limited range to keep the modulation at the same absolute frequency. Another advantage to performing the vector modulation internal to the tracking generator **20** is that the system may be calibrated with the internal modulation, or a signal generated by digital-to-analog converters (DACs) may be pre-distorted to compensate for the channel and frequency response of the rest of the tracking generator. This significantly increases the accuracy of any measurements using the internal modulation over the use of external modulation as in the prior art.

Referring now to Fig. 2 one realization of such a tracking generator **20** with an internal vector modulator **12** is shown. Baseband I/Q data is passed

from the controller **40** of the RF measurement instrument **10** to a field programmable gate array (FPGA) **14** or similar device for pre-processing, or the FPGA may be commanded to generate the broadband I/Q data from previously stored data. Alternatively the FPGA **14** may be instructed by the controller **40** to create a single or multiple unmodulated tones at specified frequencies. The digital signals from the FPGA **14** are fed into DACs **16, 18** via respective latches **22, 24**. The DACs **16, 18** create analog baseband, or near baseband, signals within their Nyquist bandwidth as dictated by a clock rate from the controller **40**. The baseband signals from the DACs **16, 18** is input to the vector modulator **12**. The modulator **12** has a pair of mixers **26, 28**, one for the in-phase (**I**) baseband signal and one for the quadrature (**Q**) baseband signal. The particular embodiment shown here modulates the baseband signals to an intermediate frequency (IF) signal, using a lower frequency local oscillator signal (LO2) from the receiver **50**, which corresponds to a first IF of the receiver in the RF measurement instrument **10**. An output stage **32** includes a mixer **34** for modulating a higher frequency local oscillator signal (LO1) from the receiver **50** with the IF signal to provide an output or test signal at an output frequency that matches a measurement frequency to which the receiver **50** is tuned.

If offset of the output signal from the measurment frequency of the receiver **50** is desired, a small amount may be generated by changing the I/Q inputs to the DACs **16, 18** during pre-processing by the FPGA **14**, such as by numerical mixing. Such an offset is desired for communications systems where a base station and hand set communicate with each other at different

frequencies. In this way transmitter/receiver band rejection may be measured. If a greater amount of offset is required, the DACs **16, 18** may be operated in a frequency band above their Nyquist band at the expense of more complex, and possibly switched, reconstruction filter requirements. In this case adaptive filters **36, 38** that filter the outputs from the DACs **16, 18** may be operated as bandpass filters rather than lowpass filters to select the frequency band above the Nyquist band -- see Fig. 3. An offset phase-locked loop (PLL) **39** may be inserted between LO1 and the input to the output stage mixer **34** to provide even larger frequency offsets by shifting the LO frequency of the tracking generator **20** away from LO1 of the receiver **50**. Also an independent oscillator **37** in the vector modulator **12** may be used instead of LO2 from the receiver **50** to provide offset, such offset being limited by the bandwidth of a bandpass filter **35** at the output of the vector modulator – the output signal still tracks LO1 of the receiver **50**.

Simpler realizations of the tracking generator **20** may be created. One possibility is to remove one of the DACs **16, 18**. In such a realization complex modulations are not generated, but the multi-tone signal may be generated at a lower cost using only the **I** signal input. Another realization is to use the DACs **16, 18** to create the signals directly at IF and remove one conversion stage if the DACs can operate at high enough sample frequencies or if there is a high enough offset in the offset PLL **39**.

As indicated above the calibration of the RF instrument **10**, using the output signal from the tracking generator **20** as input to the receiver **50**, may be used to generate parameters for the FPGA **14** for pre-distorting the data

input to the DACs **16, 18** to compensate for the channel and frequency response of the instrument.

Thus the present invention provides a tracking generator with an internal vector modulation source to provide greater measurement accuracy for an RF measurement instrument, such as a spectrum analyzer.